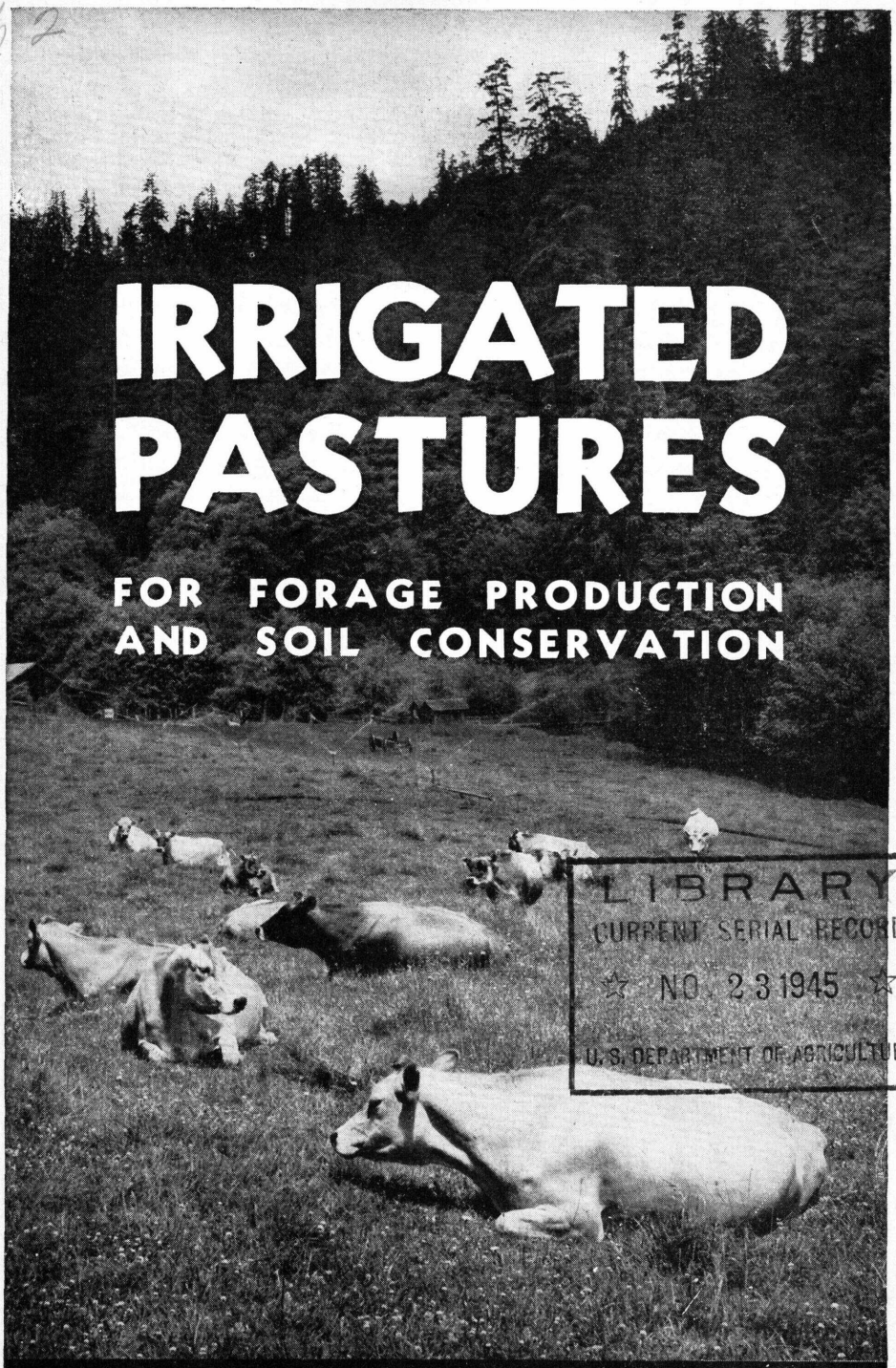

IRRIGATED PASTURES

FOR FORAGE PRODUCTION AND SOIL CONSERVATION

FARMERS' BULLETIN NO. 1973
U. S. DEPARTMENT OF AGRICULTURE

A GREAT OPPORTUNITY for expanding food production to meet needs created by the war lies in establishing and managing pastures on irrigated farms and ranches. Well-selected grasses and legumes seeded for forage production quickly develop into crops rich in food elements needed by dairy and beef cattle and by sheep. Under correct grazing use, and with the needed fertilizing and irrigation, they remain productive for periods as long as 10 years. Where native range lands are used for stock production, availability of pastures facilitates protecting the range lands from overgrazing, which would reduce their yields and lead to erosion of their soils. Irrigated pastures offer a substitute for much of the concentrated feed usually given to farm livestock, and for a large part of the usual hay rations. Finally, pasture forage costs less in labor than other feed crops.

This bulletin tells what sorts of land are suited for irrigated pastures, what grasses and legumes have greatest value as pasture plants, and how the pastures should be established, irrigated, fertilized, and managed. The information it presents applies to 17 Western States. Specific advice on selection and management of pasture plant species is given for each of five areas into which the West is divided on the basis of climate.

Washington, D. C. Issued September 1945

IRRIGATED PASTURES FOR FORAGE PRODUCTION AND SOIL CONSERVATION

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INTRODUCTION

LIVESTOCK OPERATORS on irrigated farms and ranches can make a large contribution to the present food-production effort by improving their management of pastures and establishing additional pastures. Fertile, well-managed pastures provide a livestock ration adequate in proteins, minerals, vitamins, and other essential food elements for milk production, for the fattening of cattle (aside from final finish) and sheep, and for growth of all classes of livestock, including poultry. Besides cutting down their requirements of feed concentrates, which are now hard to get, farmers and ranchmen can produce more and better livestock if they provide irrigated pastures to supplement native range. Pasture herbage costs less in labor than other livestock feeds, because it is harvested not by the farmer but by the livestock. Many farmers and ranchmen are increasing their acreages of irrigated pasture and many are improving their management of such pasture so as to increase production, but both these things can and should be done more extensively.

Pasture plants are adapted to wide ranges of environmental conditions and can be grown successfully on soils and sites unsuited to most other crops. Mixed grass-legume pastures can be made to fit into any planned crop rotation. In contrast with a stand of alfalfa, which after 3 to 5 years usually becomes so depleted that it has to be replaced with a cultivated crop, under good management a mixed pasture stand remains productive much longer and does not have to be replaced before the area it occupies is needed for cultivated crops. On some areas where production of other crops would be limited by soil erosion or a high water table, it is profitable to maintain pasture stands continuously.

[1] The authors gratefully acknowledge the cooperation of personnel of the Nursery and Engineering Divisions of the Soil Conservation Service and of Mason Hein, of the Bureau of Plant Industry, Soils, and Agricultural Engineering, whose suggestions were helpful in the preparation of this bulletin.

After the intensive cropping necessitated by the war, soils should be improved through better balanced systems of cropping and management. Production of feed at low cost will be urgently needed in the future as it is at present. Well-managed irrigated pastures can contribute to both economy of production and conservation of soil resources.

This bulletin explains why irrigated pastures have value in the farm economy and what kinds of site are suitable for this use, gives the principal characteristics and management requirements of 22 recommended pasture plant species, and tells by what methods the pastures can best be established, irrigated, fertilized, and managed. The information and recommendations it presents apply specifically to five geographic divisions referred to individually as areas I to V and collectively as the West, which are indicated in figure 1.

The term "irrigated pastures," as used here, denotes irrigated areas planted to perennial, biennial, or annual grasses and legumes for grazing by livestock.

AGRICULTURAL VALUES OF IRRIGATED PASTURES

FORAGE PRODUCTION

On a farm that is adequately irrigated, the livestock carrying capacity can usually be increased by establishing a mixed grass-legume pasture. Such a pasture, and livestock to be grazed on it, can be fitted into most farm programs by arranging to produce any additional hay and grain needed for the additional livestock at times of year when the pasture cannot be grazed, or by using steers or some other class of livestock that can be marketed at the end of the pasture season.

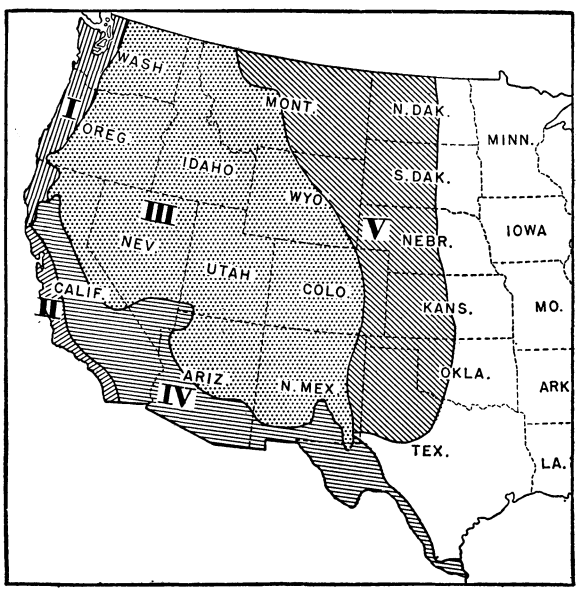

FIGURE 1.—The five climatic areas of the West referred to in this bulletin: I, Northern Pacific Coast; II, Southern Pacific Coast; III, Intermountain Area; IV, Central Valleys of California and the Southwest; V, Great Plains.

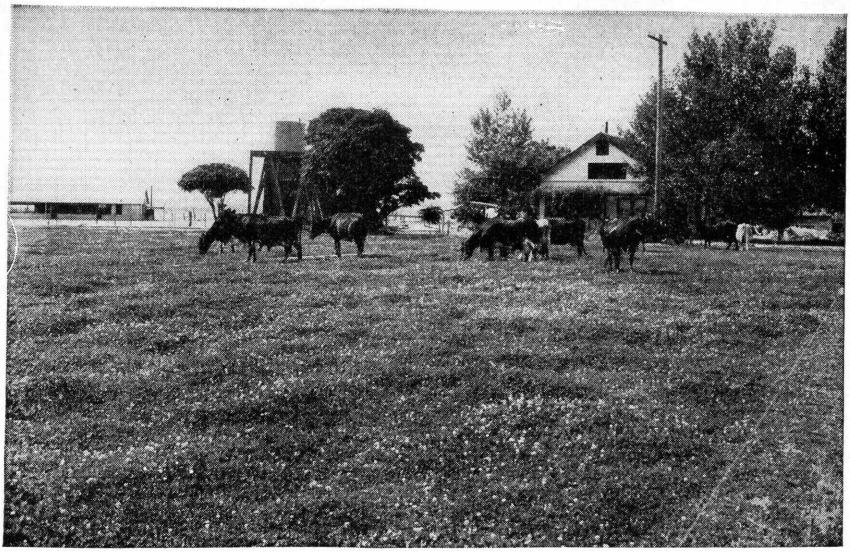

FIGURE 2.—Ladino clover pasture irrigated by the border method and grazed under a rotation system. Management is facilitated by use of an electric fence.

Aside from factors of climate, soil, and irrigation, the grazing capacity of an irrigated pasture depends upon its plant species and the kind of management it receives. Many unimproved irrigated pastures have a per acre grazing capacity of 1 animal unit[2] or less for the grazing season, but improved irrigated pastures (fig. 2) sustain from 2 to 4 animal units per acre.

The Idaho Agricultural Experiment Station found through a survey of irrigated pastures in southern Idaho that, on an average, bluegrass pastures carried 0.98 animal unit per acre but the better grass-legume pastures carried 1.6 animal units per acre. Through a similar study in eastern Oregon the Oregon Agricultural Experiment Station found that the total cow-days of grazing produced per acre per year averaged 152 for bluegrass pastures but 328 for Ladino clover-grass pastures.

In terms of feed equivalents, the forage yield of a well-managed irrigated grass-legume pasture compares favorably with that of an alfalfa field where the soil depth is suitable for alfalfa, and tends to exceed it where the soil is shallow. The Oregon Experiment Station found that the average annual per acre yield of fertilized, well-managed irrigated pastures was equivalent to 6.4 tons of alfalfa hay or 284 bushels of oats.

An example of the difference in cost between feed produced in an irrigated pasture and feed produced in a grain or hay field appears in the results of a survey made in southern Idaho by the Idaho Experiment Station. Feed costs of producing a pound of butter averaged 20 cents for the entire year, but averaged only 8 cents while the cows were on pasture.

West-coast dairymen find that under many conditions irrigation of pastures is profitable as a means of increasing summer produc-

[2] An animal unit is a 1,000-pound breeding cow or its grazing equivalent.

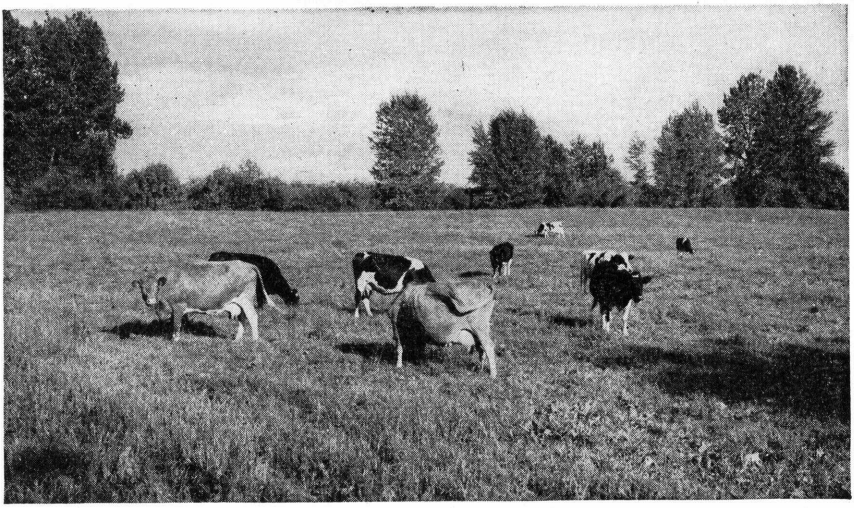

FIGURE 3.—This sprinkler-irrigated pasture is a great asset in dairy production on a Pacific coast farm.

tion (fig. 3). At the Western Washington Agricultural Experiment Station irrigation of ryegrass pastures increased dairy production 42 percent. In nearly all parts of the West rainfall is usually adequate for high forage production during the spring months, but low summer rainfall results in little pasture growth during July,

FIGURE 4.—This pasture area in California has been planted to alfalfa, orchard grass, ryegrass, and Ladino clover, and is irrigated with a portable sprinkler system. As the sole grazing area of these young herd bulls, it furnishes an ample supply of excellent forage.

August, and September on nonirrigated lands except those the soils of which have very favorable moisture conditions. Irrigation of old pastures prevents drought injury of forage plants, provides for greater total forage production, and reduces summer feed costs.

Ranchmen in range livestock areas are increasingly recognizing the value of irrigated pastures for use during periods when livestock are not on the range. Some of them are finding such pastures profitable as the sole grazing areas for beef cattle (fig. 4). Irrigated pastures used to supplement native ranges make it possible to manage the latter conservatively and thus to increase livestock production. Where an irrigated pasture is available for early spring grazing, spring use of perennial native-grass range can be delayed, and this results in greater yield of the native grasses. If a pasture crop is utilized as hay, availability of this extra feed may permit postponing use of range land in the following spring. On a ranch where range is not available in early spring, irrigated pasture may eliminate need to graze hay meadows at that time. When pasture forage is used in summer as a supplement to range forage composed largely of annual grasses the need for concentrated feeds is reduced, stock make greater gains, market animals have higher finish, the breeding herd produces more and healthier offspring, and as a result of summer protection the range improves and produces greater yields during the winter and spring grazing seasons.

Management of farm land as irrigated pasture is sometimes a means of profitably using irrigation water, available in the fall or in early spring, that would otherwise be wasted.

A well-managed, vigorous stand of pasture plants competes successfully with most perennial weeds. For this reason, long-rotation pastures are in favor in many districts where invasion by perennial noxious weeds has seriously interfered with production of cultivated crops.

SOIL CONSERVATION AND IMPROVEMENT

The dense ground cover of a well-managed stand of pasture plants prevents soil erosion on sloping lands, and the dense root systems improve the structure of the soil and increase its capacity to absorb water. Grass roots, particularly, are effective in improving soil structure. Because of their volume, density, and fibrous character they have a binding effect on light soils and a loosening effect on heavy soils, both of which contribute to tilth, permeability, and resistance to erosion. The organic matter contributed to the soil by grass roots decomposes more slowly than that contributed by roots of legumes or by annual green-manure crops. Combination of rapidly decomposing legume roots, which have a high protein content, with slowly decomposing grass roots results in prolonged benefit. Maintaining a balance of grasses and legumes leads to high sustained production of crops grown after the pasture stand is plowed under.

Soil improvement progresses most rapidly during the first few years of the life of a stand of pasture plants. Later, it tends to level off. In general, therefore, the way to take full advantage of the soil-improving capacity of pasture crops is to rotate such crops with others in regular sequence (fig. 5).

Conservation of the soil of range land results when forage production on irrigated pasture land enables a stock operator to delay

turning livestock on perennial summer range in the spring or to give range stock supplemental feed later in the season. Range land thus protected from early or intensive use is less subject to erosion.

Alkali-tolerant pasture grasses and legumes are among the best crops to grow on land that has been drained but requires leaching. Rhodes grass, Bermuda grass, western wheatgrass, strawberry clover, sweetclover, and some other grass and legume species withstand flooding better than most crops. If planted where they are adapted, these species increase water penetration and thus increase the rate at which alkali salt is removed, in addition to providing useful forage during the period required for leaching.

Irrigation may serve a secondary purpose when pasture crops are grown on sandy soils. If silt-laden irrigation water can be applied in excessive amounts, the texture and moisture relations of the sandy soils may be improved by deposition of silt. Land improvement by this means should not be undertaken if excessive irrigation would create or add to a drainage problem.

LAND USE ASPECT OF A PASTURE PROGRAM

In deciding upon an irrigated-pasture program, the grazing needs of the livestock and the capabilities of the land are considered jointly and in relation to the over-all economy of the farm or ranch operation. Grazing needs depend upon the kind and number of livestock to be kept on the farm and the type of livestock management, and land capabilities depend upon kind of soil, stoniness, slope, degree of erosion, presence of alkali, height of water table, and similar factors. Land capability maps prepared by the Soil Conservation Service are the basis for sound conservation farm planning. Help in such planning is obtained by farmers from soil conservation district organizations. When grazing needs and land capabilities have been determined, provision is made in the farm conservation plan for the acreage of pasture required, its location, the rotation of pasture crops with other crops to be grown, and any special land-management practices needed to produce pasture crops and conserve soil.

Lands suitable for irrigated pastures are those in capability classes[3] I to IV, inclusive. Class I land has no limitation in use; it is suitable for production of all locally adapted crops without any special management practices. Classes II and III are suitable for cultivation with special management practices required because of erodibility, height of water table, the presence of alkali, droughtiness, low fertility, or other conditions. Class IV lands are suited to only occasional cultivation, and are much better adapted for pasture or for hay production than for production of row crops.

A well-managed pasture is the ideal use for sloping areas of erodible soil that cannot be leveled to nonerodible grades. As irrigated pastures such areas become permanently productive. Livestock production is a suitable use also for the best of irrigated farm land (fig. 6). Good pastures are profitable wherever livestock are kept.

On irrigated lands of classes I, II, and III pasture crops should be

[3] Land capability classes recognized by the Soil Conservation Service are defined in U. S. Dept. Agr. Farmers' Bul. 1853, Classifying Land for Conservation Farming. Lands not suitable for irrigated pastures are those in classes V, VI, and VII, which are suitable only for permanent vegetation, and those in class VIII, which are not suitable for cultivation, grazing, or forestry.

rotated regularly with cultivated crops, so that they may improve the soil of the whole farm. On class IV lands cultivated crops should not be grown except in connection with reestablishing pasture crops or hay. On many farms it may be desirable and profitable to use greater acreages of class I, II, and III land than at present for pasture, espe-

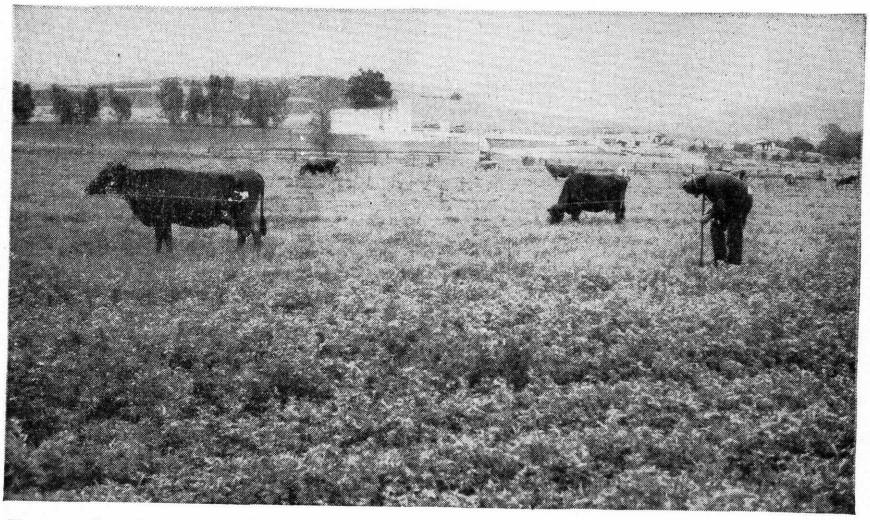

FIGURE 5.—On this irrigated land a pasture mixture including alfalfa is being rotated with general field crops, by use of an electric fence. Inclusion of alfalfa or some other legume in a pasture mixture is particularly beneficial to crops grown on the land after the pasture plants are plowed under, because it leads to an increase in available nitrogen.

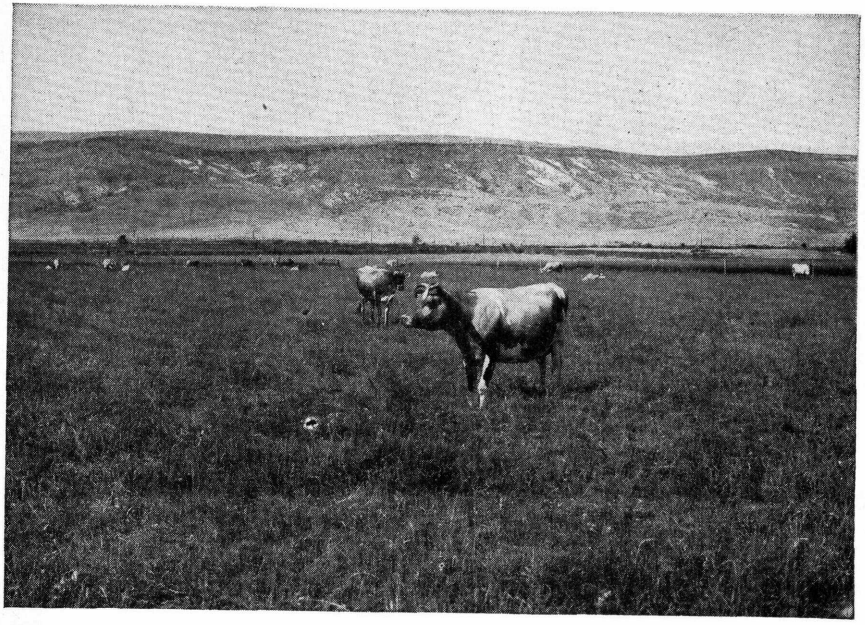

FIGURE 6.—This irrigated pasture in central Washington is producing many pounds of dairy products needed in the national food-production program.

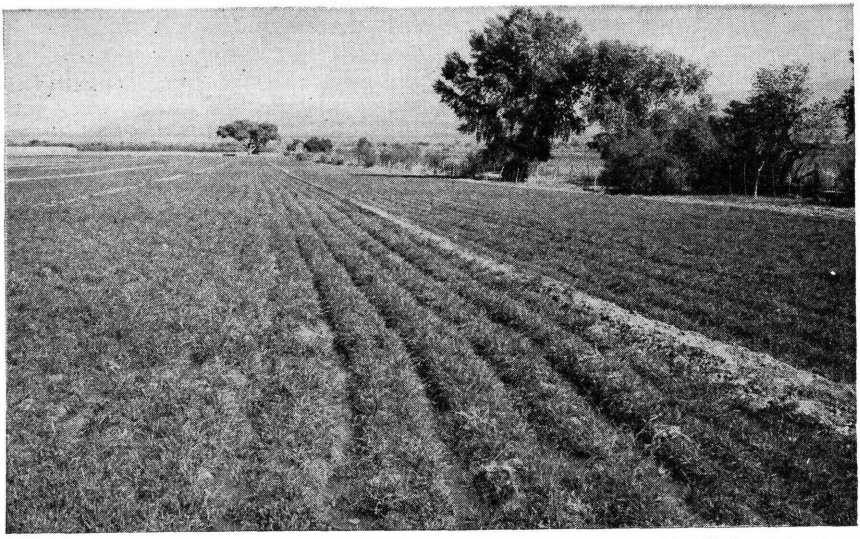

FIGURE 7.—Even distribution of irrigation water on this farm in Safford Valley, Ariz., is attained by use of both borders and corrugations. The 2-month-old seedlings need careful irrigation in order that they may quickly become well established in readiness for early grazing.

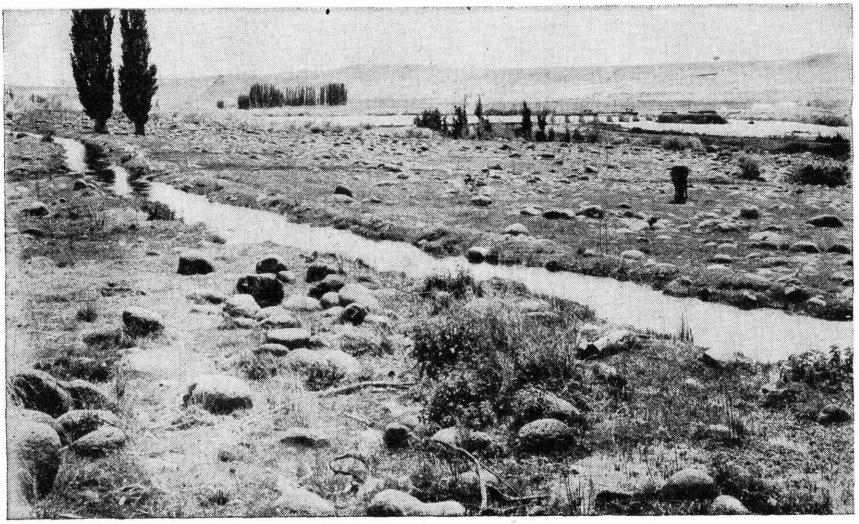

FIGURE 8.—Controlled flooding from field ditches, at relatively slight expense, has made it possible to convert this stony field in southern Idaho into a pasture having a carrying capacity of 1.75 animal units per acre per month for 7 months.

cially for pasture in rotation with cultivated crops. The better the land, the better the pasture.

The permanent productivity of a pasture depends primarily upon the quality and depth of its fertile topsoil. However, through proper irrigation and management many soils too poor in quality and too shallow for profitable production of general field crops and vegetables can be made to return very satisfactory pasture yields. Such soils

should not be expected under any conditions to give the same results as soils that are deep and fertile.

Satisfactory pasture crops can be established and maintained on all agricultural soil types. Except where efforts to bring about soil improvement through deposition of silt are practical, however, it is usually inadvisable to seed pasture plants on very sandy soil. The low water-holding capacity of such soil necessitates irrigations so frequent as to make the practice unprofitable, the soil's fertility is low, and the sod offers little resistance to injury by trampling. Heavy, tight clay soils are not ideal for pasture crops, but are more suited to them than to most other crops.

METHODS OF IRRIGATING PASTURES[4]

APPLICATION METHODS

For efficient use of irrigation water and for control of erosion while stands of forage plants are becoming established, methods of applying the water must be suited to conditions on the individual pasture area. Topography, depth and texture of soil and subsoil, and the available head of water determine what system of application is most suitable. The system chosen should make it possible to irrigate the pasture uniformly with minimum loss of water through surface wastage and deep percolation. The purpose of irrigation is to moisten the root zone. Irrigation water that runs off the field or penetrates below the root zone is lost. For many pasture plants, the root zone is so shallow that irrigating must be done with care to prevent excessive losses through percolation.

The border method of irrigation (fig. 7) is the most desirable for slopes of 3 percent or less, if soil depth permits the necessary leveling and costs are not prohibitive. In some cases very closely spaced borders have been used successfully on land where the slope was greater than 3 percent but was uniform.

Where it would not be practical to level the land for border irrigation, and on slopes of more than 3 percent where topography is broken, controlled flooding from field ditches of nonerosive grade can be practiced successfully with little erosion (fig. 8). A minimum of land leveling is required where short (or "spur") field ditches are used to carry water to high knolls or ridges. Field ditches should be spaced at intervals of about 150 feet or less, the spacing varying according to topography and soil, to facilitate uniform distribution of water and redistribution of water that collects on low areas. Ditch grades should not exceed 1½ inches per 100 feet, heads of water should ordinarily be less than 1 cubic foot per second, and take-outs should be placed at short intervals.

In establishing a pasture, corrugations may be used with either border or controlled-flooding irrigation as a means of minimizing erosion (fig. 7). Regardless of slope, corrugations may advantageously be used in establishing pasture plants on heavy soils, to help prevent soil crusting. The corrugations are usually put in after seeding and are run directly down the slope. Their spacing should be governed by the subirrigating conditions of the soil and by slope. Special care in irrigating is required, and only small heads of water

[4] For detailed information regarding irrigation methods, see U. S. Dept. Agr. Farmers' Bul. 1922, Practical Irrigation.

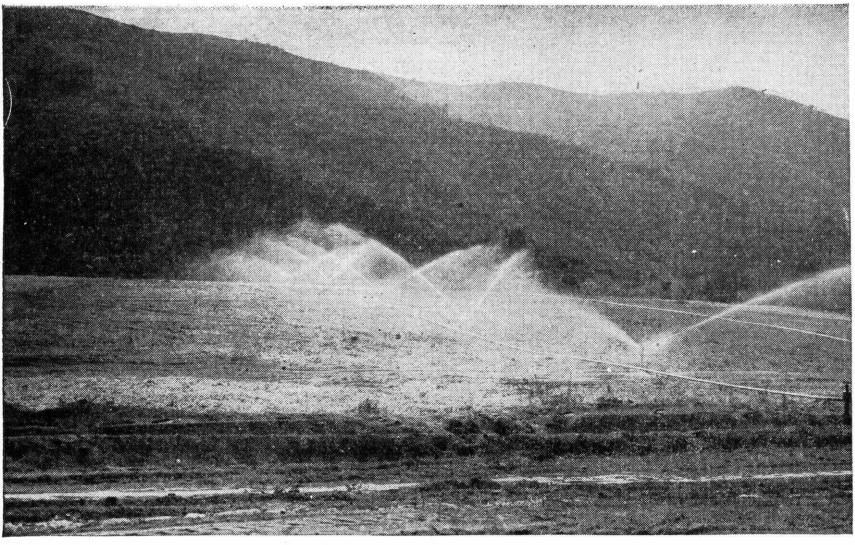

FIGURE 9.—This newly broken land, too rough for economical leveling, is being sprinkler-irrigated for the first time in preparation for development as a pasture.

can safely be used, until the grasses have sodded the corrugations sufficiently to stabilize them against erosion. After stands are established, corrugations used with either controlled-flooding or border irrigation tend to deteriorate. On rough topography, corrugations should be cleaned and maintained throughout the life of the planting.

Sprinkling is probably the best of all methods of irrigation for pastures from the standpoint of efficient utilization of water supply, but the initial cost limits its practical use. Sprinkling is especially desirable on areas of rolling topography and on soils with low water-holding capacities, such as sandy loams. Land may justifiably be irrigated by sprinkling where the water supply is too limited for the use of other methods or where the soil is too shallow or the cost of leveling too high to permit the leveling necessary for border irrigation (fig. 9). Whether the cost of sprinklers is economically justifiable must be determined individually for each farm.

A guide for use in determining desirable width and length of irrigation border strips and spacing and length of corrugations according to the general character of the soil, on an area having a slope not greater than 3 percent, is offered in table 1. On slopes greater than 3 percent, the width of border strips should be limited to 15 feet and their length to 300 feet. Horizontal spacings recommended for field ditches according to the slope of the area to be irrigated are as follows:

Slope (Percent)	*Spacing (Feet)*
0 – 3	150
3 – 8	100
8 – 12	75–50

The grade of field ditches should be 1½ inches or less per 100 feet. Take-outs should be provided about every 20 to 30 feet, according to topography.

RATES AND FREQUENCIES

An irrigated pasture requires about the same seasonal total of irrigation water as an alfalfa field, but requires smaller, more frequent applications. Water moves slower over land covered with a well-managed pasture sod than over land in alfalfa or small grain, but penetrates the sod-covered soil faster. For the sod area, therefore, relatively larger heads of water may be necessary to obtain quick coverage and efficient distribution of moisture in the root zone.

TABLE 1.—*Approximate dimensions for border strips and corrugations to be used in irrigating areas having slopes of 3 percent or less that are to be seeded and developed as pastures*

General soil classification	Border-strip dimensions		Corrugation dimensions	
	Width	Length	Distance apart	Maximum length
	Feet	*Feet*	*Inches*	*Feet*
Sandy soils	15–20	200–300	18	200
Medium loams	20–30	300–400	24–30	300
Clay loams	30–40	400–660	18–24	440

To determine how much water should be applied at one time to a given pasture area, it is best to measure depth of penetration, with a soil auger or soil probe, after each of a series of irrigations until the operator learns the approximate length of time required for a given quantity of water to penetrate to the desired depth. In general, pasture needs are met by applications of 2 acre-inches each. On an area having a grass cover, however, it is usually difficult to obtain the desired penetration at the lower end of the irrigation run without applying 3 acre-inches.

Within any climatic area, how often a pasture should be irrigated depends primarily on characteristics of natural precipitation and varies with plant species and with soil texture and depth. Usually the desirable interval ranges from 7 to 18 days (table 2). In sandy soils, after a thorough wetting, from ½ to 1 inch of water per foot of soil depth is retained and therefore is available to the plants. In loam soils, from 1 to 2 inches of water per foot remains available. Obviously, sandy soils require more frequent, lighter applications of water than loams. The same thing is true of some heavy clay soils. Where alkali has accumulated at the soil surface,

TABLE 2.—*Usual range of desirable frequency of irrigation for pastures on soils of different textures*

General soil classification	Approximate amount of water readily available to plants per foot of soil depth after irrigation	Desirable frequency of irrigation
	Inches	*Days*
Loamy sand	0.8	5–12
Sandy loam	1.0	7–14
Silt loam	1.3	12–18
Clay loam	1.1	7–14
Clay	.9	7–14

and subsurface drainage is adequate, more frequent irrigation may be required to maintain the downward movement of alkali.

Because most pasture plants are subject to winter injury when dry, a late fall or early winter irrigation is desirable for pastures in climatic areas where winter precipitation does not supply the roots with adequate moisture. There should be no such irrigation if the water would be likely to form a cover of ice that would smother the plants.

A schedule of rates and frequencies drawn up with reference to precipitation averages and to soil texture and soil depth may be adjusted to variations in weather.

SPECIES SELECTION, SEED QUALITY, AND SEEDING RATES

Each plant species to be used in establishing an irrigated pasture should be selected for its adaptation to the climatic and site conditions, its grazing qualities, and its seasonal rate of production. For species of only moderate palatability, high yield capacity and seasonal growth rate should be primary considerations in selection. Table 3 presents information on the adaptation, growth characteristics, palatability, and management requirements of the principal grasses and legumes recommended for use in irrigated pastures within the different climatic areas of the West indicated in figure 1.

USE OF GRASS AND LEGUME SPECIES IN MIXTURE

Two or three grasses plus one or two legumes are usually an adequate number of species for the pasture mixture. Using a greater number of species seldom adds any value to the mixture, and complicates seeding and management.

Grass species differ as to seasons of flush growth, dormancy, and near dormancy. Some grasses grow most rapidly during the cool weather of early spring and others during the warm weather of late spring and summer. Species that grow rapidly in cool weather are desirable for use on areas where irrigation water for pasture use is available only in the fall or in early spring. Where water is available only in late spring or in summer, species that start growth late and produce most heavily during warm weather should be used. Where water is available in both spring and summer, grass species having different seasonal growth periods should be selected for use in mixture, so that the pasture, under good management, may produce the most uniform possible yield of high-quality forage throughout the grazing season.

Where water is available only in late spring or in summer, and where delivery periods are far apart, no species should be used that cannot resist drought.

On sloping lands one sod-forming grass should be included in the mixture, to provide a dense turf resistant to trampling and to soil erosion. Under some conditions it may be desirable to include in the mixture a small proportion of a rapidly developing, short-lived grass to control weeds and erosion until the slower growing, longer lived grasses and legumes have become established.

Legumes are valuable in the pasture mixture in that they (1) contribute substantially to volume growth, especially during spring and

summer; (2) are richer in protein and some minerals than the grasses; (3) give variety to the forage and, being highly palatable, contribute to high-volume consumption of forage and thus to high gains of the grazing animals; and (4) if inoculated, take part with soil bacteria in fixation of nitrogen from the air, reduce the need for applying nitrogen to the pasture as fertilizer, and increase the amount of nitrogen available in the soil to crops used in rotation with the pasture mixture. Legumes should make up at least 30 percent and not more than 50 percent of the number of plants in the pasture stand. If constituting more than 50 percent, they may create serious danger of bloat.

ADAPTATION TO CLIMATE AND SOIL

Most pasture species well adapted to northern climates characterized by relatively low summer temperatures do not produce well in southern areas having long, hot summers. They are somewhat better adapted to high than to low elevations in the southern areas. Lack of winter hardiness limits the northward range of many species adapted to warm southern climates. On the Pacific coast, where temperatures are mild during both summer and winter, species have a greater north-south range of adaptation than elsewhere in the West. Strains adapted to inland climates characterized by warm summers and cold winters seldom tolerate Pacific coast conditions, although other strains of the same species may do so. Alfalfa and some other species have strains adapted to all the climates represented in the West. So far as it is possible to make a selection among varieties and strains of species, those best adapted to the environmental conditions and to the intended use should be selected.

In general, grasses and legumes are adapted to wide ranges of soil and other site conditions. Deep-rooted legumes are not adapted to shallow soil, or to soil having a high water table. Both grasses and legumes differ in their adaptation to wet, poorly drained soils and to alkaline soils, and only species of known tolerance should be included in mixtures seeded on such soils. Mixtures to be used on very sandy soils should include deep-rooted legumes and sod-forming grasses. Where silt-laden irrigation water is to be applied in excessive amounts to sandy pasture soils, in order that the soils' texture and moisture relations may be improved through deposition of silt, only species known to be tolerant of flooding and silt deposition should be used. Where it is desired to increase the permeability of a soil perennial grasses should be used, because of their large numbers of small roots.

QUALITY OF SEED

It pays to use only high-quality seed of known origin, purity, and percentage of germination. If sold through commercial channels, seed is labeled as to percentage of purity, percentage of germination, and weed content. Pasture seed containing noxious weed seed should not be purchased. Before purchasing seed from neighbors, farmers should assure themselves that it is true to name and is of high quality.

High-quality seed costs more than poor-quality seed, but the cost risks of using seed of poor quality are far greater.

TABLE 3.—*Principal grasses and legumes recommended for use in seeding irrigated pastures: their adaptation, growth characteristics, palatability, and management*

GRASSES

Species	Major climatic, soil, and site adaptation	Seasons of major growth	Productivity	Other growth characteristics	Palatability	Management and related factors
Alta fescue (*Festuca elatior* var. arundinacea)	Areas I, II, III, and IV, and southern part of area V. Adapted to wide variety of soils; tolerates moderately wet soils, moderate alkali, and scarcity of water.	Makes most rapid growth in spring and continues to grow well through summer and fall. (In areas I, II, and IV, growth continues during winter.)	High	Long-lived; not sod forming; slow to become established; coarse but leafy; bunchy; growth more uniform than that of meadow fescue.	Medium	Requires careful grazing management or clipping to maintain leafiness and high palatability; adequate irrigation and fertilizing important, to maintain succulent growth.
Crested wheatgrass (*Agropyron cristatum*)	Areas III and V. All well-drained soils of medium to low fertility; tolerates light alkali.	Early spring and fall	Medium	Long-lived; not sod forming; slow to become established.	Medium	Survives close grazing; loses palatability rapidly as it approaches maturity; cannot compete successfully under irrigation proper for mixtures; recommended only where water supply is inadequate for other cool-season grasses and where there are high spots that cannot be irrigated.
Dallis grass (*Paspalum dilatatum*)	Areas II and IV. Adapted to wide variety of soils, but prefers heavy soils; tolerates alkali, flooding, and poor drainage.	Spring, summer, and early fall.	High	Long-lived; slow to become established, but aggressive thereafter; basal growth leafy; ergotized spikelets poisonous to livestock.	High	Requires frequent grazing and may require mowing to prevent forage from becoming stemmy and unpalatable; widely used in mixture with clover to provide summer grazing in area IV; soil fertility requirements for maximum production high.
Harding grass (*Phalaris tuberosa* var. stenoptera)	Areas II and IV, and warmer parts of area III. Prefers heavy soils but does well on light soils underlain by heavier subsoils. Fertility level more important than soil type.	Fall, winter, and spring	High	Long-lived; not sod forming; slow to become established; coarse-stemmed but leafy; leaves mostly basal.	High	Requires frequent grazing to maintain high palatability; principal value for winter and early spring grazing either in pure stands or in mixture with a winter legume; free from pests and diseases; use and adaptation not well known; seed supply limited at present time.
Common (or Italian) ryegrass (*Lolium multiflorum*)	Areas I, II, IV, and V. All well-drained soils; tolerates moderately wet soils.	Early spring in northern and fall, winter, and very early spring in southern areas. (In area IV, no growth during summer months.)	High	Annual or biennial; becomes established very rapidly; offers severe competition hindering establishment and growth of long-lived perennials; dormant in hot weather; reseeds if allowed to head.	High	Withstands close grazing after reaching height of 6 inches; volunteers if allowed to seed late in season; valuable in parts of areas I and IV for temporary or supplemental pasture; soil fertility requirements for maximum production high.

Kentucky bluegrass (*Poa pratensis*)	Areas II, III, and IV. Adapted to wide variety of soils; does not tolerate drought or excessive alkali.	Early spring and fall. (Growth slow during periods of high temperature.)	Medium	Perennial, sod forming, aggressive, shallow-rooted; effectively controls erosion.	High	Responds well to nitrogen fertilizer; requires frequent irrigation; soil fertility requirements for maximum production high.
Meadow fescue (*Festuca elatior*)	Areas I, II, III, IV, and V. Adapted to wide variety of soils; tolerates moderately wet clays and slight alkali.	Late spring, early summer, and late fall.	Medium	Medium long-lived; not sod forming.	High	Requires careful grazing management to maintain palatability; may require clipping; being replaced by Alta fescue where latter is adapted; dependable; valued especially for late-fall grazing.
Meadow foxtail (*Alopecurus pratensis*)	Areas I and III. Adapted to wide variety of soils, including heavy soils; survives flooding; requires excellent seedbed.	Very early spring, summer, and fall.	Medium	Long-lived; sod forming; slow to become established, but aggressive thereafter.	High	Withstands close grazing; requires clipping to keep down seed heads; should be fertilized heavily; seed scarce and high-priced; seeding facilitated by processing seed.[1]
Orchard grass (*Dactylis glomerata*)	Areas I, II, III, IV, and V. All well-drained soils; not tolerant of wet soils or alkali.	One of earliest to start growth in spring; fall growth rapid. (Summer production only fair.)	High	Long-lived; easily becomes established; aggressive; shade tolerant; mature forage harsh; makes rapid regrowth; tends to become bunchy, especially if pasture stand is thin.	High under proper management, otherwise medium.	Requires frequent grazing to maintain palatability; may require clipping; subject to winter drought injury; some strains subject to rust on coast.
Perennial ryegrass (*Lolium perenne*)	Areas I and II, cooler parts of area IV, and warmer parts of areas III and V. All well-drained soils of good fertility; tolerates moderately wet soils.	Spring and fall. (Growth continues well into summer in cooler parts of areas II, III, and V. In warmer parts of areas II and IV growth continues during winter.)	Medium	Medium long-lived; not sod forming; easily becomes established; develops rapidly; very leafy; competes strongly with slower growing perennials.	High	Responds well to nitrogen fertilizers; major use in area I; rusts badly in central coastal area of California; soil fertility requirements for maximum production high.
Reed canary grass (*Phalaris arundinacea*)	Areas III and V. All soils of medium to good fertility; better adapted to wet soils than any other species; tolerates moderate drought.	Spring. (Growth continues well throughout summer and fall.)	High	Long-lived; slow to become established; develops rapidly thereafter; leafy but coarse; makes rapid regrowth.	Medium	Grazing control or mowing necessary to keep forage from becoming too coarse; most palatable when not more than 12 inches high; does not survive continuous close grazing; nitrogen application prevents sod binding and increases yield; not highly desirable for sites where other recommended forage plants are adapted; seldom desirable for use in mixture.

[1] For instructions, see U. S. Dept. Agr. Cir. 558, Processing Seed of Grasses and Other Plants to Remove Awns and Appendages.

TABLE 3.—*Principal grasses and legumes recommended for use in seeding irrigated pastures: their adaptation, growth characteristics, palatability, and management*—Continued

GRASSES—Continued

Species	Major climatic, soil, and site adaptation	Seasons of major growth	Productivity	Other growth characteristics	Palatability	Management and related factors
Rhodes grass (*Chloris gayana*)	Areas II and IV, especially sections of area IV where growing season is milder and longer. (Usually does not survive temperature below 10°F.) Adapted to wide variety of soils; prefers heavier soils; tolerates alkali and moderately wet soils.	Spring, summer, and early fall.	High	Long-lived; sod forming; once established, aggressive; roots at nodes; medium-stemmed, leafy; excellent seed provider.	Medium	Requires frequent grazing and sometimes mowing to maintain palatability; free from pests and diseases.
Smooth brome (*Bromus inermis*)	Probably best adapted of grasses to areas III and V. Adapted to all soils of good to high fertility; tolerates light alkali and light flooding.	Late spring, early summer, and fall. (Makes slow growth in summer when temperatures are high. Growth stopped by fall frosts.)	High	Long-lived; sod forming; slow to become established; some certified strains very leafy.	High, reduced by fall frosts.	Does not withstand continuous close grazing; responds well to nitrogen fertilizers; northern strains less productive in southern areas of adaptation than local strains, and vice versa; soil fertility requirements for maximum production high.
Tall oatgrass (*Arrhenatherum elatius*)	Areas I, II, and III. All well-drained soils; not tolerant of wet soils or alkali.	Starts growth very early in spring. (Summer production fair.)	High	Not sod forming; becomes established rapidly, makes rapid growth.	High under proper management, otherwise medium.	Does not survive close grazing; seed should be de-awned to facilitate seeding.[1]
			LEGUMES			
Alfalfa (*Medicago sativa*)	Strains adapted to all areas. Medium light to heavy deep soils; not tolerant of poorly drained or acid soils, or soils having high water table; tolerates light alkali.	Late spring, summer, and early fall.	High	Tall-growing perennial; easily and quickly becomes established; highly competitive if ample soil moisture is always available.	High	Injured by continuous close grazing; should be allowed to make several inches of top growth in fall; bloat hazard high, reduced by growing in mixture with grasses; should be seeded at rates of not more than 2 to 5 pounds per acre.
Alsike clover (*Trifolium hybridum*)	All areas, except hot interior valleys of area IV. Medium-light to heavy soils; tolerates poorly drained and acid soils.	Late spring, summer, and fall.	Medium	Short-lived; easily becomes established; taller growing than Ladino clover.	High	Must be allowed to reseed; injured by close grazing; of value primarily on soils too wet for most other legumes.

California bur-clover (*Medicago hispida*)	Areas II and IV. Prefers medium to heavy soils rich in lime, but tolerates noncalcareous and alkaline soils.	Fall, winter, and early spring in southern areas. (Semidormant in winter north of Bay region of California.)	High	Annual; develops rapidly; reseeds naturally. Burs have high nutritive value.	Medium	Should not be grazed if ground is soft; of value to extend pasture season; burs objectionable in sheep grazing.
Ladino clover (*Trifolium repens* Ladino)	All areas, except extreme southern parts of region. Medium-light to medium-heavy well-drained soils; not tolerant of alkali; slightly tolerant of acid.	Spring, summer, and fall	High; continues through great part of season.	Medium long-lived; roots at nodes, but less than white and strawberry clover; shallow-rooted; plants larger than white clover; recovers rapidly after moderate grazing.	High	Injured by close and continuous grazing; requires frequent irrigation; especially valuable on shallow soils; should not be grazed late in fall; bloat danger reduced by growing in mixture with grasses.
Red clover (*Trifolium pratense*)	Strains adapted to all areas. Medium-light to heavy soils; slightly tolerant of acid.	Spring, summer, and early fall.	High	Biennial; becomes established rapidly.	High	Injured by continuous close grazing; major use in mixture with alfalfa or Ladino clover for first-year grazing.
Strawberry clover (*Trifolium fragiferum*)	Areas III and V and cooler parts of area IV. Especially well adapted to continuously wet soils; most alkali- and salt-tolerant legume; survives long flooding.	Spring, summer, and fall	Medium	Long-lived; slow to become established; low growing; roots at nodes.	Medium	Withstands close grazing; seeds spread in manure of grazing animals.
Sweetclover (*Melilotus alba* and *officianalis*)	Areas III, IV, and V. All soil types; not tolerant of acid; tolerates moderate alkali.	Spring and summer	High	Biennial, but because of hard seed coats some new seedlings may be produced every year.	Medium	Becomes coarse and unpalatable if allowed to grow much above 12 inches in height; of greatest value on alkaline soils and in short-lived pasture mixtures on rotation cropland; should be used in mixture with grass.
White clover (*Trifolium repens*)	Areas I, III, IV, and V. Medium-light to heavy soils; not tolerant of alkali.	Spring, summer, and fall	Medium	Long-lived; slow to become established, but persistent thereafter; low growing; roots at nodes; fine-leaved.	High	Withstands heavy and close grazing better than other legumes except strawberry clover; adapted strains should be used.

[1]For instructions, see U. S. Dept. Agr. Cir. 558, Processing Seed of Grasses and Other Plants to Remove Awns and Appendages.

TYPICAL RECOMMENDED SEED MIXTURES

Typical seed mixtures recommended for different site conditions in each of the five climatic areas of the West are listed below. Since conditions affecting the desirability of given mixtures vary within each of the areas, it is always advisable to consult the State agricultural college, the county agent, an extension agronomist, a soil conservation district officer, or a local representative of the Soil Conservation Service regarding choice of a mixture.

Area I, Northern Pacific Coast:	*Pounds per acre*
A. Well-drained soil:	
Perennial ryegrass	2
Orchard grass	4
Alta fescue	6
Ladino clover	3
Red clover	3
B. Poorly drained, heavy-textured soil:	
Alta fescue, or	8
Meadow foxtail	6
Ladino clover	3
Area II, Southern Pacific Coast:	
A. Well-drained soil:	
Perennial ryegrass	2
Orchard grass	4
Alta fescue	6
Ladino clover	3
B. Poorly drained soil, moderately alkaline or nonalkaline:	
1. Central California	
Italian ryegrass	2
Alta fescue	6
Alsike clover	2
White clover	2
2. Southern California:	
Dallis grass	4
Rhodes grass	6
Strawberry clover	2
Sweetclover	2

Area III, Intermountain Area:	*Pounds per acre*
A. Well-drained soil:	
Smooth brome	6
Orchard grass	4
Alta fescue	6
Ladino or white clover	2
Red clover	3
B. Poorly drained soil, moderately alkaline or nonalkaline:	
Smooth brome	6
Alta fescue	6
Strawberry clover	3
C. Areas where irrigation water is not plentiful:	
Smooth brome	6
Crested wheatgrass	4
Alfalfa	5
Area IV, Central Valleys of California and the Southwest:	
A. Well-drained soil:	
Perennial ryegrass	2
Dallis grass	4
Orchard grass	4
Ladino clover	2
Alfalfa	3
B. Poorly drained, moderately alkaline or nonalkaline soil:	
Dallis grass	4
Rhodes grass	6
Strawberry clover	3
Sweetclover	2
Area V, Great Plains:	
Alfalfa	4
Smooth brome	14

ESTABLISHING IRRIGATED PASTURES

An operation to establish a grass-legume pasture on irrigated land should be carried out with great care. Reasons for effort to obtain a good stand include the high value of irrigated land, the relatively high fixed water charges and taxes, the cost of seed, and the fact that grass-legume mixtures are a perennial crop.

Seeding intended to convert lands heavily infested with perennial weeds into permanent pastures should be deferred for not less than 1 year, and preferably for 2 years, during which time tillage or some other effective cultural measure is practiced to thin out and weaken the stand of weeds.

SEEDBED PREPARATION

A fine-textured, firm, moist, fertile, and weed-free seedbed is necessary for successful establishment of small-seeded pasture grasses and legumes. A firm seedbed reduces the danger of seeding too deeply, holds moisture near the surface, and so favors uniform germination and emergence. Weeds, if not controlled, offer serious competition to young pasture plants. A fertile seedbed, well supplied with moisture, makes it possible for the plants to grow vigorously.

Tillage required to prepare a firm and weed-free seedbed varies according to the previous crop. Plowing is most often advisable in preparing the seedbed for a pasture crop following a small grain, but disking may be sufficient after production of an annual row crop. Disking, harrowing, and packing are logical steps in seedbed preparation. If the soil is dry, irrigation prior to seeding is desirable to firm the seedbed and germinate weed seed. A cultipacker or similar implement is very useful for firming a seedbed that has not been thoroughly firmed by irrigations and harrowing.

Where the border method of irrigation is to be used, the ridges should be constructed after the land has been plowed and worked down. The land should then be carefully leveled between the borders and irrigated. Further leveling may be needed to eliminate low spots and side fall between the ridges.

If manure is used, it should be disked into the surface soil during seedbed preparation. There it will serve more effectively in nourishing the plants than if plowed under. Where soil tests can be made to determine whether phosphates and potash should be applied and if so at what rates, this should be done; otherwise, reliance must be placed on observation of the vigor of the pasture plants and their rates of growth. Ability to judge requirements of mineral fertilizers on the basis of such observation increases with experience. Phosphates should preferably be applied before plowing, but may be applied after plowing or with the manure. Nitrogen fertilizers should preferably be worked into the surface soil during the final operations of preparing the seedbed, but may instead be applied at the time of seeding. Nitrogen fertilizers should not be brought into contact with the seed, or they may hinder germination.

Packing is desirable as the last operation in preparing a seedbed, to assure firmness of surface. It is especially important where establishment depends on moisture already in the soil or on expected rain.

TIME OF SEEDING

On areas that are to be irrigated, most perennial grasses and pasture legumes can be seeded either in late summer and fall or in the spring. Some grasses such as Dallis grass and Rhodes grass do not germinate in cool weather and must be planted in the spring, or early enough in the fall to have 10 weeks or more of growing weather before frost. Other fall seedlings should have from 6 to 10 weeks of growing weather to ensure resistance to cold. In general, the grasses capable of growing in cool weather are more resistant to cold in the seedling stage than the legumes.

If the seedbed can be prepared in time, and ample moisture is assured, late summer or early fall seeding has certain advantages over spring seeding. Fewer irrigations are required for establishment,

weed competition is less, and earlier grazing will be possible the following year. Late summer or early fall seeding is distinctly preferable to spring seeding on sites infested with most perennial weeds.

RATE OF SEEDING

The rate of seeding should be based on the percentage of live pure seed in the species lots making up the mixture. A seeding rate of from 16 to 20 pounds per acre is ample for most mixtures of high-quality seed. An increase in rate of seeding is not a fit substitute for good seedbed preparation. Broadcasting rates should be slightly higher than drilling rates. When seedling diseases or alkali problems are involved, rates of seeding should be increased.

METHOD OF SEEDING

Drilling is preferable to broadcasting, as it facilitates uniform distribution of the different species in a mixture and planting at the desired depth. Seeding depth should never be more than 1 inch, and for some small-seeded species it should not be more than ¼ inch. Seeding at the desired depth is facilitated also by a firm seedbed. Depth-control gages may be used on disk furrow openers to ensure proper depth of seeding, or, if the surface of the seedbed is loose, the drill spouts may be removed and tied behind the disks, so that the seed will drop into the partially filled furrows. For small grass and legume seed the grass-seed attachment should be used. If seed of different species to be included in a pasture mixture are similar in size, smoothness, and other physical characteristics, and so are to be drilled together, the different lots should be thoroughly mixed together before they are placed in the drill box. The drill should be equipped with an agitator in the grain box and should be calibrated to seed as nearly as possible at the desired rates.

Satisfactory pasture stands can be obtained by broadcasting. A good plan for obtaining uniform distribution of species in broadcast seeding is to go over the field twice, first in one direction and then in the direction at right angles to it, broadcasting at half the chosen seeding rate each time. Large, heavy legume seed should be broadcast separately from small, light grass seed, not mixed with them. Packing the soil with a corrugated roller before and after broadcast seeding is advisable. Most of the seed fall into the shallow furrows left by the roller and are covered by the second rolling.

INOCULATION OF LEGUMES

Legume seed should always be inoculated unless experience in using the same legume species in the field that is to be seeded shows this is unnecessary. Even if inoculation is not necessary it may prove beneficial, promoting vigorous early growth. Unless inoculated either with bacteria already present in the soil or artificially, legumes must obtain nitrogen from the soil the same as nonlegumes.

COMPANION OR NURSE CROPS

Companion crops retard the establishment of stands of pasture plants, by shading or smothering the plants and by competing with them for nutrients and moisture. Use of such crops is advisable, however, where early grazing is desired and where a rapidly developing plant cover is necessary for erosion control.

The less leafy, shorter-strawed varieties of grain are preferable to tall, leafy varieties as companion crops, because they cast less shade. The seeding rate of cereal grain used for this purpose should be not more than 20 to 30 pounds per acre.

Use of a companion crop necessitates more frequent irrigation.

IRRIGATION DURING ESTABLISHMENT

To assure conditions satisfactory for establishment of all species in the mixture, the surface soil should not be permitted to crust or dry out within the first 18 to 20 days after seeding. Where precipitation does not meet this need the seedings should be irrigated. From two to five irrigations may be required, depending on soil type, drying conditions (temperature and wind), and the amount of rainfall received. Spring-seeded pasture crops often require one to three more irrigations for establishment than those seeded in the fall.

The first irrigation should be made with a small head of water, to avoid disturbing soil and seed. So far as possible, the soil should be moistened to a depth of a few inches only.

FERTILIZING IRRIGATED PASTURES

The fertilizer requirements of irrigated soils vary greatly not only within each of the five climatic areas of the West but even between fields on the same farm. Like other farm lands, pastures must be fertilized if they are to produce the highest yields. While a field is in use as a pasture, plant nutrients are constantly drained away from it in the form of milk, meat, and other animal products. Some nutrients are returned to the soil in manure and through decay of plant material, and if inoculated legumes are present the nitrogen content of the soil is amplified by fixation of nitrogen from the air; these contributions, however, do not counterbalance the drain. Also, of course, in many cases a pasture soil is poor in nutrients as a result of previous cropping or is naturally deficient in some nutrients. By correcting soil deficiencies, fertilizing can increase yields, provide earlier spring grazing, improve forage quality, and aid in weed control.

In fertilizer studies at the Utah Agricultural Experiment Station, the following increases in yields of forage from mixed grass-legume pasture were obtained through fertilizing: Ammonium sulfate at the rate of 200 pounds per acre, 21.5 percent; treble superphosphate at 200 pounds per acre, 37.5 percent; treble superphosphate and ammonium sulfate each at 100 pounds per acre, 45.2 percent; manure at 20 tons per acre, 24.6 percent; and manure at 10 tons per acre plus treble superphosphate at 200 pounds per acre, 34.3 percent.

The mineral fertilizers most generally needed are nitrogen and phosphorus. Potassium and sulfur are beneficial on some areas.

NITROGEN

Grasses are heavy feeders on nitrogen, and the most satisfactory grass yields are obtained only when an ample supply of nitrogen is readily available in the soil. If legumes in the pasture mixture are properly inoculated, nitrogen for their growth and also for growth of the grasses becomes available through fixation from the air. Even so, grasses usually respond favorably to nitrogen fertilizers, in both volume production and protein content.

Sources of nitrogen include farm manures and commercial nitrogen carriers such as ammonium sulfate, sodium nitrate, and ammonium nitrate. A ton of barnyard manure contains on an average about 10 pounds of nitrogen. Ammonium sulfate, sodium nitrate, and ammonium nitrate contain about 20 percent, 16 percent, and 35 percent nitrogen, respectively. Rates of application of these materials should be based on their nitrogen content.

Where legumes tend to retard the growth of grasses or crowd them out, application of nitrogen increases the vigor and volume growth of the grasses and contributes to maintenance of the desired pasture stand composition. Under these conditions, it is profitable to apply 75 to 100 pounds per acre of ammonium sulfate, or an equivalent, to mixed grass and legume pastures in early spring. For pure grass pastures, commercial nitrogen fertilizers are especially helpful in obtaining maximum yields. Grasses in pure stands require heavier applications of nitrogen than stands containing inoculated legumes.

Nitrogen should be applied in early spring, or at whatever time rapid growth is most desired.

PHOSPHORUS

For pasture mixtures containing legumes, most irrigated soils become more productive if fertilized with phosphorus. Soils low in organic matter, or soil on which legumes, sugar beets, and other crops that are heavy feeders on phosphorus have been grown, almost always respond markedly to applications of phosphates. At the Utah Experiment Station an application of 200 pounds of treble superphosphate increased forage yields 37.5 percent, and at the Oregon Experiment Station an annual application of 300 pounds of superphosphate per acre increased the forage yields of a mixed grass-Ladino clover pasture approximately 50 percent.

Critical deficiencies in available phosphates are evidenced by slow growth of legumes. Even where legume growth appears satisfactory, applying phosphates frequently results in increased yields. Phosphates applied to pasture soils deficient in phosphorus encourage the growth of legumes in relation to that of grasses, and help maintain the desired proportion of legumes in the mixture. At the Utah Experiment Station, legumes composed 34 percent of the stand on pastures fertilized with treble superphosphate as compared with 19 percent where only nitrogen was applied.

Forage grown on soils that are deficient in available phosphorus does not contain enough phosphorus to meet the needs of livestock. This deficiency can be corrected by applying phosphates.

Desirable rates of application of phosphates per acre per year range from 100 to 300 pounds of treble superphosphate or its equivalent. Phosphates may be applied to pastures at any season of the year. Fall or early spring application is usually desirable to bring about maximum production early in the grazing season.

POTASSIUM AND SULFUR

Potash is usually available in sufficient quantities for pasture purposes in the soils of the West. In some cases, however, especially on fields that have been producing row crops under irrigation for many years, application of muriate of potash or its equivalent at a

rate of 50 to 100 pounds per acre may be beneficial to Ladino clover or other legumes in the mixture. Applications of potash in addition to nitrogen and phosphorus give beneficial results on some soils in western Washington, Oregon, and California, and to a limited extent elsewhere. Peat and muck pasture soils usually respond to application of potash. Where potash is deficient, fertilizers may be purchased as single ingredients or as a 3–12–4, 4–16–4, or similar mixture.

Legumes respond to applications of sulfur on many soils in northern Idaho, western Oregon and Washington, and California. Sulfur may be applied as gypsum or as elemental sulfur. Gypsum is the preferred form for use on acid soils, as it does not increase soil acidity. Sulfur is usually applied at a rate of 75 to 100 pounds per acre of gypsum, or the equivalent, before seeding and each year thereafter during the life of the pasture stand.

LIME

In most irrigated areas of the West the soils are highly calcareous and application of lime is not needed. Acid soils occur only in the high-rainfall areas along the Pacific coast. Here Ladino clover, which tolerates a considerable degree of soil acidity if phosphate needs are adequately met, is the legume commonly used in irrigated pastures, and a desirable response to application of lime is not usually to be expected from any but extremely acid soils.

BARNYARD MANURE

Both grasses and legumes respond favorably to applications of barnyard manure. At the Caldwell Experiment Station, in southwestern Idaho, top dressing with manure combined with proper irrigation increased pasture yields as measured by milk production nearly 50 percent. The Utah Experiment Station reports increases of approximately 24 percent in yield of forage from pastures fertilized with manure or with manure plus phosphates. The beneficial effects of manure are due largely to the nitrogen it provides and to the effects of organic matter in increasing the activity of soil bacteria and improving soil structure. Manure is low in phosphorus. On an average a ton of it contains, together with about 10 pounds of nitrogen and 5 pounds of potash, only 5 pounds of phosphorus. On manured pasture soil deficient in this element phosphates should be applied, especially if the plant mixture contains legumes. A good practice is to apply the phosphates together with the manure, and a better one is to add them to the manure during the period of accumulation and storage. Phosphates added to manure as it accumulates in storage reduce the loss of nitrogen through leaching and ammonification.

Manure may be applied in the fall, in early or late winter, or in early spring. If applied in the fall or early winter, it is broken down by moisture and freezing and is more easily worked into the turf the following spring, and this results in earlier spring grazing. Applications made in late fall, winter, or early spring should be evenly distributed with the spreader and should be harrowed so as not to cover vegetation excessively.

For most efficient use, manure should be applied at a rate of 8 to 10 tons per acre. Lighter or much heavier applications seldom produce

a response proportionately as great. At this rate of application, the manure produced on the average farm is sufficient to cover only about one-third of the farm acreage each year. Also, on many farms the manure can ordinarily be used more profitably for the general field crops. Consequently, manure alone usually cannot meet the entire fertilizer needs of pasture.

LIQUID MANURE

Liquid manure, which contains some solids as well as the animal urine, is especially valuable for fertilizing irrigated pastures. Provision for its storage and use on dairy farms has not received the consideration it deserves in this country. However, its use is expanding on the northern Pacific coast. At the Western Washington Experiment Station irrigated dairy pastures fertilized with liquid manure produced 13 percent more forage than those not fertilized.

Liquid manure should be used in light applications after each rotational grazing period and before irrigation rather than in a single heavy annual application. The amount that should be applied varies according to the concentration of the solution, which is governed by the amount of wash water used in flushing the manure from stalls or yards into the storage tanks. An equivalent of 10 tons of barnyard manure per acre is considered a good annual rate of application. When used on pasture stands containing legumes, liquid manure should be supplemented with phosphates. During hot summer weather, in order to avoid burning the foliage the manure should be applied when ground and plants are dry, and irrigation should follow within about 24 hours. If irrigation within that time is not possible, application of the manure should be omitted.

MANAGING IRRIGATED PASTURES

Success in producing pasture forage depends largely upon how the pasture is managed. The objectives of good management are to maintain the desired composition of high-yielding grasses and legumes, to use the forage when it is most nutritious, and to keep the pasture plants growing vigorously during the grazing season. These objectives can be attained in part through such measures as rotation grazing and weed-control practices.

PROTECTION OF NEW SEEDINGS

New seedings should be protected from grazing until the plants are securely anchored to the soil with good root systems. In the north, ordinarily pastures seeded in late summer should not be grazed until late the following spring. In southern desert areas fall-seeded pastures may be grazed about 3 months after seeding, when the tall-growing grasses have made 8 to 10 inches of top growth. Spring-seeded pastures should not be grazed until late summer.

During the first year's growth a pasture should not be grazed when the soil is wet, and should not be grazed closely at any time. In southern desert areas close summer grazing is particularly damaging to young stands, as it subjects the plants to injury from a combination of high temperatures and drought. In the north close fall grazing is most harmful, as it prevents storage of food reserves for winter protection and early spring growth.

Newly seeded pastures should be mowed to reduce competition from weeds and to prevent weeds from reseeding. To prevent scalding of the pasture plants, the cutter bar should be raised to cut high.

ROTATION GRAZING

Under the rotation grazing system a pasture is divided into three or more units and these units are grazed, irrigated, and rested in turn throughout the grazing season. This system favors maintenance of the vigor of stands, because it excludes close continuous grazing on any part of the pasture. The periods of irrigation and rest provide for uniform regrowth over the entire pasture area. The heavier rate of stocking for short periods and the uniform growth of forage facilitate uniform grazing, and utilization of the forage when it is most nutritious. Livestock are off the pasture during and immediately after irrigation, when the ground is wet and trampling would damage the sod. All these factors contribute to high yields. In a test at the Western Washington Experiment Station rotation grazing, as compared with continuous grazing, resulted in forage yields 9 percent greater.

For improved irrigated pastures the three- and four-unit rotation grazing systems are widely applicable. Under the three-unit system the regrowth period in each rotation cycle is twice as long as the grazing period, and under the four-unit system it is three times as long. A five-unit system, with a minimum of 5 days between the last irrigation before grazing and the first irrigation after grazing, is desirable for some pastures on very sandy soils. The rapid drying rate of such soils permits grazing 2 days after irrigation. The frequency of irrigation required and the summer growth rate of the pasture plants are good guides in determining the number of days that should be selected as the rotation cycle. Except for first grazing in the spring, grazing may be so planned as to harvest the forage when it has reached a height of 6 to 7 inches. Ordinarily, regrowth to this height is made in a period of 2 to 3 weeks if the soil is fertile and the pasture has ample irrigation. If spring growth is so rapid that the forage cannot be adequately used by the grazing animals, one pasture unit should be left ungrazed and its vegetation used as hay or silage. It is never advisable to irrigate the pasture during grazing or later than 2 days before grazing. Table 4 shows regrowth periods, grazing periods, and frequencies of irrigation for typical rotation cycles under the three-, four-, and five-unit pasture systems.

TABLE 4.—*Typical rotation grazing cycles for 3-, 4-, and 5-unit pastures*

Pasture units (number)	Rotation cycle	Regrowth period	Grazing period	Least time between last irrigation before grazing and next irrigation
	Days	*Days*	*Days*	*Days*
3	18	12	6	9
	21	14	7	10
	24	16	8	11
	27	18	9	12
	30	20	10	13
4	16	12	4	7
	20	15	5	8
	24	18	6	9
	28	21	7	10
5	15	12	3	5

The rotation grazing system can be fitted into the management plan of any farm. Where it is desired to move high-producing cows, or fattening livestock, to new pasture every few days and have the clean-up grazing done by dry cows and young stock, each of the pasture units can be subdivided and the units can be irrigated and otherwise managed in pairs as a three- or four-unit system. On many farms periods between deliveries of irrigation water, necessary field arrangements in regard to irrigation or drainage ditches, and other factors may determine what rotation plan is best.

Under any system of rotation grazing, the same pasture unit should not be grazed first every year. Rotation of first grazing among the different units contributes to maintenance of plant vigor and yield.

SEASON OF GRAZING AND RATE OF STOCKING

In general, spring grazing on the first pasture unit should start as soon as the soil is firm and dry enough to withstand trampling and the pasture plants have attained a height of 3 to 4 inches or, if they are of tall-growing species, approximately 6 inches. If grazing is delayed longer, much of the forage may develop beyond the stage at which it is most palatable and nutritious.

In early spring the forage is washy and not so nutritious as it will be when the plants are a little nearer maturity. To prevent overgrazing of the first pasture unit, it may be necessary to shorten the first period of grazing by a few days.

Grazing should stop in the fall in time to allow the plants to make some top growth for winter protection and build up root reserves. Plants that are closely grazed until freezing weather are more subject to winter injury and are slow to start growth the following spring. The period of greatest food storage in the roots is in the fall, when the growth of the plants slows down but the leaves continue to manufacture food. If the top growth is not grazed off in the fall, food manufactured in the leaves after grazing ends is transported to the roots for storage over winter and stimulates the plants to make early growth the next spring.

Both understocking and overstocking of pastures should be avoided. Understocking results in spot grazing, and is likely to result in waste because the ungrazed portion of the herbage becomes unpalatable and may have to be mowed. Also, grasses lose protein content as they approach maturity. Grasses in a vigorous and succulent stage of growth contain from 16 to 18 percent or more protein. This diminishes to about 7 percent or less when the plants have headed, and drops still farther at the seed stage. Consequently, for highest returns a pasture should be stocked at a rate that permits utilization of the forage when it is in a vigorous growing condition. If more forage is available than the stock can utilize, a portion of the pasture can be fenced off for hay production. Overstocking to the extent that the vegetation is kept closely grazed throughout the season reduces the plants' vigor and yield and finally results in stand depletion.

The grazing capacity of pastures is highest during the spring, when the plants are growing most rapidly. If a pasture is stocked on the basis of its spring grazing capacity, overstocking occurs during the summer and fall. To avoid this, supplemental pasture can be used during the summer and fall, or sufficient irrigated pasture acreage can be provided to carry the livestock during the summer and

fall seasons and the excess of spring forage can be utilized as hay. As the growth of pasture plants slows down during the summer the amount of concentrates fed to high-producing dairy cows or fattening livestock should be increased. Pasture mixtures composed of tall-growing grasses should be so grazed that their height will not be reduced to less than about 4 inches during the grazing interval.

TEMPORARY PASTURES

For temporary pastures of annual plants to supplement pastures of perennial plants during seasons when they produce little or no forage, Sudan grass, millets, legumes, and small grains are recommended. Small grains sown in early fall provide limited grazing in the fall and early spring, and, in warmer climates, during the winter, with little or no reduction in grain yields. Winter oats or winter barley is preferable for areas where winterkilling is not a problem, and winter rye for colder areas. If it is found advisable to use a small grain exclusively as pasturage, one of the clovers should be planted with it. Biennial sweetclover (fig. 10) or Hubam sweetclover seeded with small grain provides late pasturage after the small grain has been harvested. Sudan grass is the favored temporary summer pasture crop for areas to which it is adapted. However, it is strictly a warm-weather grower, and, like other sorghums, must not be planted until the soil is warm. It may cause poisoning if grazed before it has grown to a height of about 15 inches or if grazed too soon after irrigation when it has stopped growing because of lack of soil moisture. Sudan grass may cause poisoning also if it is grazed within a few days after frost. Common (or Italian) ryegrass and California bur-clover seeded in early fall supplement summer-growing species such as Dallis grass and Ladino clover.

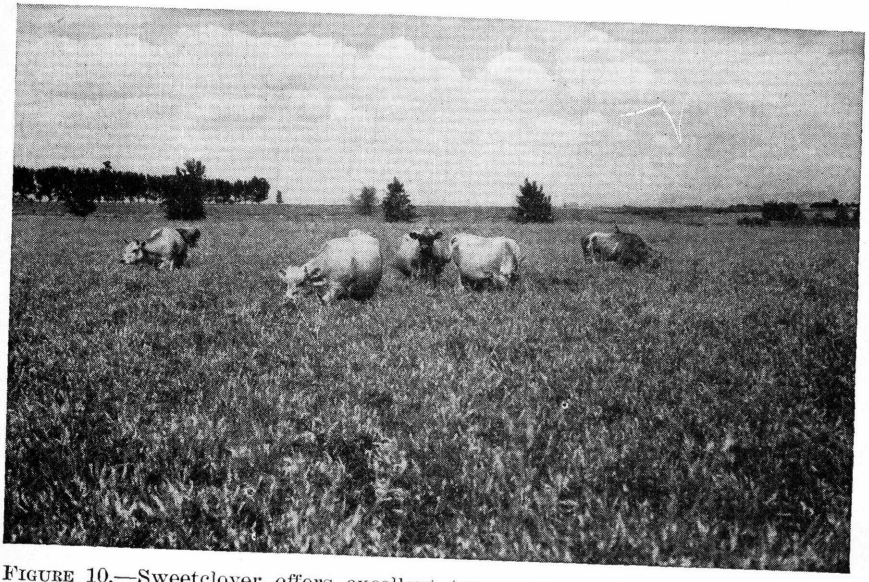

FIGURE 10.—Sweetclover offers excellent temporary grazing for even the best dairy herds. For highest palatability, it should not be allowed to grow much taller than 10 or 12 inches.

MOWING

Mowing, aside from hay production where excess herbage is available, should be considered almost solely an emergency measure in pasture management. Properly managed pastures require very little if any mowing. Underutilized pastures require occasional mowings. Most weeds are less palatable than the grasses, and should be mowed

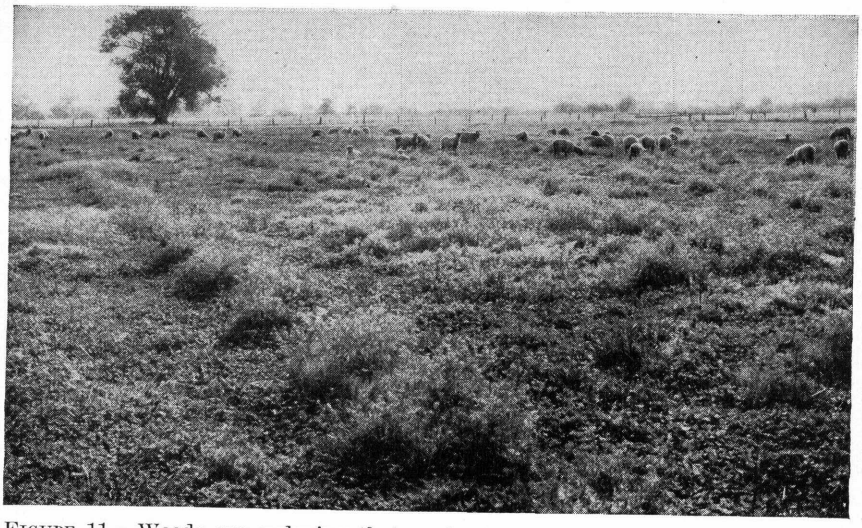

FIGURE 11.—Weeds are reducing the grazing capacity of this pasture. Mowing would control the weeds and provide for more uniform grazing.

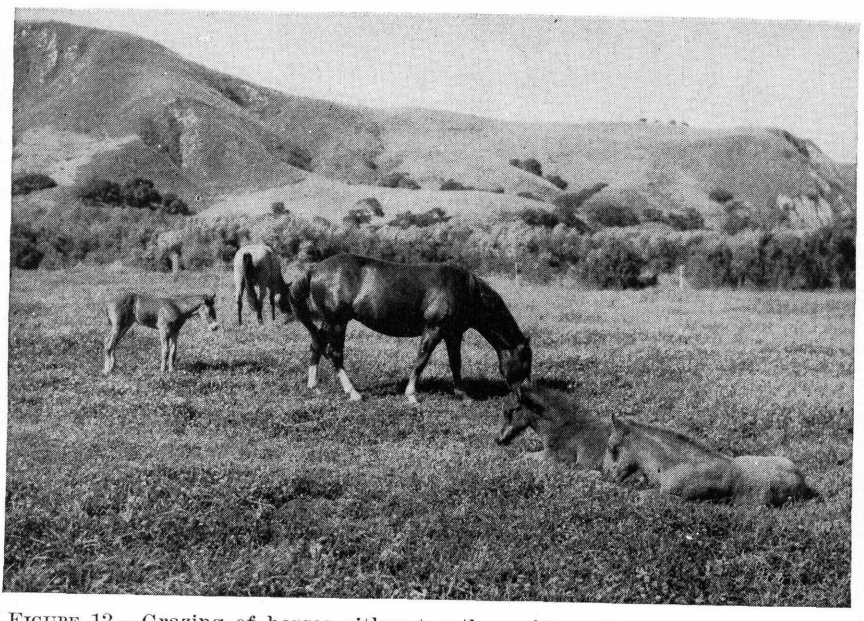

FIGURE 12.—Grazing of horses either together with cattle or in rotation with them makes for better control of vegetation. Irrigated grass-legume pastures produce healthy, strong horses.

to prevent them from spreading seed and competing increasingly with pasture plants for nutrients, moisture, and light (fig. 11).

Clipped forage may be left on the pasture area or, if the amount justifies it, harvested as hay or silage. If forage is mowed 2 days before livestock are removed in the rotation grazing cycle, the stock eat much of the clipped material and any remainder has time to dry sufficiently not to interfere unduly with the next irrigation.

SPREADING DROPPINGS

Animal droppings should be spread by harrowing or some other method. This effects better utilization of the manure as fertilizer and more even utilization of the forage. If droppings are not spread they smother the plants under them and become surrounded by rank forage that is avoided by the grazing livestock, with the result that grazing capacity is considerably decreased. Grazing by cattle and horses together or in rotation (fig. 12) or by cattle and sheep together assures better utilization of the forage next to animal droppings but does not eliminate the smothering effect. All pastures should be harrowed once either in late fall or in early spring before growth starts and two or three times, according to need, during the summer. Harrowing is easier and more effective if it follows a slow rain or an irrigation.

BLOAT CONTROL

Bloat has always been a problem in cattle and sheep production and is particularly troublesome in connection with grazing livestock on certain legumes. Any of the legumes used for pasture purposes may cause bloat in cattle and sheep if the forage is young, succulent, and especially palatable. The tendency of legumes to cause bloat ranges from low to high among species and from very low to high among the different climatic areas of the West. Alfalfa is usually the most productive and in many places is the most palatable of all pasture legumes, and alfalfa forage retains its soft and succulent nature when the plants are approaching the blooming stage, at which time, being taller, they can easily be topped to the exclusion of the grasses. After being grazed, alfalfa recovers rapidly and soon again overtops the grasses. For these reasons, in many districts pasture managers believe that the bloat hazard is greater for alfalfa than for any of the other pasture legumes. In some other districts the bloat hazard of alfalfa is considered not to be serious, especially if one or more tall-growing grasses are grown in mixture with the alfalfa.

Two years' observations made by nursery personnel of the Soil Conservation Service on the grazing choice of livestock among a large number of grasses and legumes growing in mixtures near Albuquerque, N. Mex., indicated that alfalfa was the most palatable and that it had the highest tendency to cause bloat of all the legumes under observation. Considerably more grass was eaten along with each of the clovers tested than with the alfalfa when the stock were first turned on the pastures at the beginning of each grazing period.

Bracken and Evans, of the Utah Agricultural Experiment Station, suggest these methods of guarding against and treating bloat:

1. Let no more than 35 to 40 percent of the permanent pasture stand consist of legumes.

2. Keep salt and water readily available at all times.
3. Partially fill animals with hay before turning them on legume pasture.
4. Keep hay or straw in a manger in every legume pasture.
5. In localities where the bloat hazard is considered serious, allow pastures preponderantly of legumes to reach a fairly advanced stage of growth before turning stock on them.
6. Give bloated animals antiferment treatments, such as ½ ounce of formalin or 1 ounce of turpentine as a drench. Mix formalin with water and turpentine with milk.
7. In severe cases, puncture the distended stomachs with a trocar or knife.

In general, agricultural experiment station workers and pasture managers recommend that legumes constitute not more than half the forage volume of any pasture. This maximum should be accepted as an ideal. The best known method for maintaining any desired ratio of perennial legumes grown in combination with grasses is through the use of fertilizers and grazing management.

ASSISTANCE THROUGH SOIL CONSERVATION DISTRICTS

In addition to general technical information made available through Federal and State agencies, a farmer or ranchman undertaking to establish an irrigated pasture is likely to need specific, on-site assistance from technicians. Assistance of this sort is now available to farmers and ranchmen within areas that have been organized, through cooperative action, as soil conservation districts. Usually the first step is to make a conservation survey of the farm, showing—field by field—the kinds of soil, the extent to which erosion has injured the site, the degree of slope, the present land use, and the capability of the land to produce. A conservation plan for the entire farm is worked out, which provides for rotating pasture crops with other crops in orderly sequence so as to obtain the greatest possible benefit from the plant nutrients stored under the pasture sod and contains practical recommendations for land use and soil management. The pasture field is laid out in such a way that the most efficient distribution and utilization of irrigation water can be obtained, and advice is given regarding seedbed preparation and selection of pasture species.

Under some conditions the job of developing an irrigated pasture calls for land leveling or ditching equipment not made available to the farmer by contractors at a charge he can afford to pay. Use of such equipment is now being supplied to farmers at reasonable rental by many soil conservation district organizations.

Cooperative assistance to the individual farmer, including technical assistance from the Soil Conservation Service, through organization of soil conservation districts is now provided for by law in 47 States.

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